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ABSTRACT

In teaching a well-organized college physics course that is understandable to students, teachers should first understand students' conditions and circumstances and be clear on the goals of the course. The goals of physics teaching are commonly defined as understanding the nature of scientific reasoning and the concepts and methods of physics, while requirements tend to consist of verbally embedding special physics skills and performing mathematical calculations. The main goal of introductory courses, however, should go beyond the teaching of special skills and help students recognize the characteristics of processes. The theme of introductory physics courses should be reorganized according to the learning processes of the mind and its forms of understanding. In the context of physics instruction, understanding means that individuals can abstract the common features of events observed in nature and recognize which theorems and terms apply to observed motions and bodies. In addition to reorganizing the course, teaching methods should be renewed, shifting from the traditional lecture format to small group assignments that involve collective problem solving and discussion. If physics is worth teaching, it should be taught in a way that most benefits the students. (BCY)

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Organize the Theme and Renew the Method for Teaching Excellence in College Physics

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ORGANIZE THE THEME AND RENEW THE METHOD FOR TEACHING EXCELLENCE IN COLLEGE PHYSICS

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Abstract

The paper discusses and gives an answer to the question of how to teach an understandable physics. Among the academic subjects, mathematics serves for teaching students the logical way of thinking. Physics should serve to teach them to notice, that in nature there are processes. Some events cause others and everything is in constant motion and in constant change. This view of nature can be taught well by the simplest science, that is, physics. Because of its simplicity the numerical side of physics has reached a very high level. However, mathematics--which is an advantage for physics in research work--becomes a disadvantage in teaching physics. At least 80% of the problems assigned for solution in teaching are formal repetition of the mathematical form of the theorems or laws of physics. Only the words which are used in the problems are "practical" words. That form of practicing physics stiffens the way of thinking of the students. Instead of understanding the processes in nature by physics, in the thinking of students stubborn algebraic formulas and letters represent physics. For this reason, it is quite natural that after leaving school these formulas will drop out of mind and students will remember their physics teacher--with whom they had human-like associations--rather than physics itself.

Problem

In this paper the writer wants to discuss the problems in teaching physics and an approach to teaching it which may produce better results. However, the title of the presentation may concern each of the subjects taught in colleges.

If one wants to organize, one should know the conditions, the given circumstances and the goals. In teaching, the main condition is determined by the students who are taking part in the education process. They have knowledge which has been obtained in their previous education and thoughts have been are determined by the society in which they are living.

Rewards

It is interesting to compare students of the writer's native country, Hungary, to the students in the United States. In Hungary the population has been living for years in the socialist system or as it is referred here, communism. The socialist system wanted each member of society to be an average person doing her/his work at an average level. Excellent work, generally, was not honored. The life of students after finishing their education was not dependent upon their excellent results in school but rather on the students, or parent's "socialist connections". Students, mainly boys, were generally not hard workers at school, and they wanted to go through the exams at only an average level.

Comparatively, students in the United States want good grades because they are honored. However, it is the impression of the presenter that the students want the good grades from the work of the teachers. Everywhere in their life, daily advertisements on television, they are offered something for money. They have unknowingly developed the feeling that knowledge from their teachers for the money they are paying. However, teachers can give grades but cannot give knowledge. Unfortunately, some teachers feel pressure to give the grades.

Another aspect, which all subjects have in common, is the learning process; this writer believes that although the mind is very good for repetitive verbal learning, for "parrot"-like learning, it also is very good for abstract learning. Therefore, one can give response to not only previously known situations but to ones which have not been met earlier. However, the formation of this kind of knowledge is difficult and to measure its efficiency is nearly impossible. It is realized only in the long run. Traditional teaching prefers verbal-like knowledge because it is measurable.

Skills

The aim of a subject in the teaching process is to provide a special skill which is characteristic to the subject. In the organization of the theme of a subject a significant problem arises in the decision of which subject should be taught under the conditions of the fast rate of change of our world and our technologies. What is worthwhile to be embedded and what is worthwhile to be discussed? Many times the educational process is surmounting obstacles before obtaining the deserved reward, the diploma, just as in fairy tales the goods got their rewards after overcoming obstacles. Meanwhile, the students in current learning or in newer ones, forget what they have learned earlier. (The students need the empty space in their brain for the short period memorization of the newer and newer data). What is the sense of learning? What are the requirements for being educated? These goals are defined in the curriculum, but the implantation and its continuous control are done by the organizing work of teachers.

In school mathematics skill in calculations with numbers, with algebraic expressions and, at a higher level, skill in calculus is wanted. However, it is important that mathematics, beyond the formal skill, should teach the ability to recognize logical connections and to put into mathematical formulas the simplest relations we meet in every day life.

The goals of physics teaching are defined in the curriculum: Understanding the nature of scientific reasoning and the concepts and methods of physics. The main goal of introductory physics teaching should, in the writer's belief, go beyond the teaching of special skills (just as learning a language goes beyond the learning of words), to show the recognition of the characteristics of processes. We meet processes are in our everyday life which always change the world around us, and these changing processes governed by the constant laws of nature. The simplest processes are investigated by physics; for this reason, by physics we can learn the simplest way to recognize and understand the characteristics of processes. The understanding of processes means we know the causes of them, how they could be changed, and at what rate they could be changed. This would be important not only for students majoring in physics, but for all the students taking part in general education. This goal should determine the theme of introductory physics, and the learning and understanding process of the instructor should determine the structuring of the material and the method of teaching.

At the present stage of introductory physics teaching, besides the requirements of verbally embedding special skills, mainly calculations with numbers or with algebraic expressions or the mathematical-like solution of problems given in words are required. This means the practice of some mathematical skills rather than physics.

Renewal

It is necessary to organize the theme and renew the method, but it's a problem doing it for a single physics teacher. It is a program for the process of introductory physics teaching. We should, and we can, organize the theme of introductory physics teaching according to the learning process of our mind and the possibilities given by the present stage of technology.

In current textbooks one can find the same structuring and discussion of the material following the convention developed historically. This way of introductory physics teaching goes against the understanding process of the mind and the internal logic of the physical theories. This is the reason physics is considered a difficult subject to understand. Additionally, in many investigations it was shown that the conceptual understanding of students, even of those who are majoring in physics and/or learning at the graduate level, is very poor in the basic concepts of physics which were discussed at the introductory level.

Understanding means we are able to abstract the common features of various events we observe in nature. Abstraction can be reached by way of investigation and analysis of similar and different observations. A frame for this analysis is needed and this is offered by the proper physical theory. Abstraction should begin with the picturesque events of mechanical motions.

The theory of mechanics, the frame of Newton's laws, gives the basis for the organization of our first abstractions. The main statement of Newtonian mechanics is that the variety of motions is caused by the variety of forces acting. By the laws and concepts of mechanics we may understand the variety of motions and we can predict motions which we did not observe before. Think on the motion of space crafts and the voyage to the moon.

How should introductory physics proceed from the concrete to the abstract, which is the way of understanding? One should show first the variety of motions; one should show at the very beginning not only free fall, motions along a slope and projections of point like bodies, but even vibrations, pendulum motions and any kind of motion that we can show for point like bodies. It could be the interpretation of the motion of the electrons according to the figure on the screen of an oscilloscope. Afterwards we should show motions of rigid bodies; then the motion of deformable bodies, vibration of strings, perhaps plates may follow. The variety of motions presented depends upon specific circumstances (time constraints or shortage in equipment) we have. The discussion of motions should easily be made by video recording with high resolution and listening to the slowed down playback. In the description of various motions the application of various coordinates and frames of reference could be learned together with the usage of vectors.

After making acquaintance with various motions one may start the understanding process, and learn why they are different. The differences can be learned between the abstract terms of physics, as force, energy, momentum, and angular momentum by practicing them in the discussion of various motions. The concept of force has a central role in the understanding of motions. However, the start of its discussion should be first without motion only under static conditions. Under static conditions one should meet not only "free" forces like gravitation and spring force but even constraint forces appearing due to the attributes of the surrounding bodies acting on the examined body: various frictions, the strains along deformed surfaces, strings and wires. It is very good to work at this point with buoyant force, and with electrostatic and magnetostatic forces. This composition of the usage of forces in static conditions makes it possible to gain a deeper understanding of forces.

In the dynamic investigation the parallel application of the concepts and theorems of mechanics should be used in the discussion of motions observed at the beginning. In the application of the variety of physical concepts it should be discussed under what conditions one or the other is simpler to apply. It should be shown how the various dynamic concepts are used for the forecast of particular events. After the forecast we have to do the measurement in the experimentation of the process. In this way, as one proceeds through a few observations, it will be obvious to the students what the aim of physics is and what we can do with the help of physics.

In the integration of the physical discussion it is important to concentrate always on the same theorems and laws and not on the various motions and bodies, as it is done nowadays in textbooks. The discussion of the various motions of various bodies is not important, but the realization of the various physical concepts and theorems in various motions is important. The recognition of which theorem and what kind of terms are simpler to use with this or that kind of motions of this or that body represents true understanding.

This was the organization of the material and of work with the students. How can one renew the method of teaching? As previously described the guiding and organizing work of the teachers in the teaching process is the key.

The conventional way of teaching is lecturing on the material, thinking that if something is told to the students they will know it. This kind of teaching is the heritage of the era when printed or other type of copies of the material to be known was not easily obtained. Nowadays one has the textbooks, and many of them. As, faculty, we may want the students to learn the material from books in the way we guide them. For this reason the interpretation of the material with summary and proper experiments is advisable at lectures. It is not worthwhile to spend too much of the time which is given for the subject in a semester with conventional lecturing. Much of the time should be organized to work with the students in small groups as collective problem solving and discussion with the guidance of teachers or in introductory laboratory work with a lot of guidance to show what is worthy of observation and which way it should be done. One must not leave the student alone assuming that they are able to find and discover the things what were previously achieved by very clever and hard working, interested researchers previously during longer, and not limited, time.

Physics education is required to prepare students for oral and written presentation of their knowledge. The written part can be done in a part of examination in the form of so-called essay questions, the titles of a which are to be given previously during the presentation and discussion of the material at lectures. The oral part of the training of students can be done by their presentation of the solution of assigned problems or experiments. The other students

may question and criticism. Additional questions from the teacher are important in these cases. This oral presentation could be a control of the individual work of students during the semester.

Very important, perhaps, the most important point in the understanding process the individual work of students. In textbooks the material is discussed in a definite way. The learning of it, by copying and/or by memorizing, is not good; it does not lead to understanding. Assigning problems for solution helps to repeat the discussed material in another way than it is discussed in the text book, but using strictly numerical problems stiffens the discussed material, hiding the changes which are characteristic of processes. It is better that in a problem only a part of the task should be calculation; a bigger part should be analysis. Giving questions for analysis is good, but we meet two problems in it: One problem is with the student, how they will know the answer is right, and another problem is with the teachers, how to evaluate the answers if they have a lot of students. The method of true and false statements is better than others. However, it is not easy to prepare false statements that seem to be true. If you prepare your discussed material with true and false statements, the students have the opportunity to learn the material with understanding, and at the exam the teachers have the opportunity to measure the understanding of the students in a fast way. An offered form for kind of statement is presented in the handouts for the various parts of introductory physics teaching.

True-false statements are also better for the evaluation of the knowledge of students than multiple-choice type of questions. In multiple-choice questions the student can relate the given statements to each other, which may help to find the answer. In true-false statements there is only one statement that must be related to the knowledge of the student. That type of control of the knowledge can be sharpened by asking for a short explanation of the answer, or in order to block student "gambling" the application of negative points could be considered.

Evident Problems

Regarding the circumstances for physics teaching, we have two kinds of problems for teachers are evident. In big colleges or universities the main form of teaching is the conventional lecture, the efficiency of which is nearly zero (students have two ears: one for the information going in and the other for its going out; both are working with the same efficiency). There are shortages of teachers and rooms to have more lessons or introductory laboratories in small groups. The control of the individual work of students in large numbers is nearly impossible. Assistance is not teaching. To be a good teacher you need to know the subject, have special teaching training and a strong desire to teach.

In small colleges the smaller number of students is very good for a proper education; however, assistance for the work of physics teachers is sometimes missing. At colleges there are many kinds of assistance (even for controlling the parking rules), but assistance for science teachers in preparing experiments or buying the necessary materials for them is not given. It is much easier to do blackboard physics, as mathematics is done, but at least double time is necessary if you want to perform physics teaching by the really worthwhile method with experiments.

If physics is worthwhile to be taught, and it is, then it should be done the way in a manner in which students benefit.

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